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Forest Health Protection

Pacific Southwest Region
Northeastern California Shared Service Area

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To: District Ranger, Mt. Hough Ranger District, Plumas National Forest

Subject: Insect and Disease Evaluation of the Wildcat Project (FHP Report NE14-02)

Summary

At the request of Alex Yiu, Assistant District Silviculturist, Mt. Hough Ranger District, Danny Cluck, Forest Health Protection Entomologist, conducted a field evaluation of the Wildcat Project on November 22, 2013. The objective of this visit was to evaluate current stand conditions, determine the impacts of forest insects and diseases on management objectives and discuss treatment alternatives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing stand density and increasing resiliency to disturbance events such as insect outbreaks, drought and fire. Alex Yiu participated in the evaluation.

Key findings:

- Several native forest insects and diseases were found throughout the project area contributing to tree mortality including bark beetles, dwarf mistletoe and root disease.
- Overstocking is putting many stands at risk to high levels of bark beetle-caused tree mortality during periods of drought.
- Mixed conifer stands and Jeffrey pine stands have become denser with a higher proportion of white fir in the absence of fire.
- Many stands have experienced high levels of white fir mortality during current and recent drought periods.
- Dwarf mistletoe infection levels are high in some Jeffrey pine stands reducing tree vigor and predisposing trees to bark and woodboring beetle attacks.
- High fuels loads, consisting of an abundance of dead-down trees and a dense understory of live trees have put many stands at risk to stand replacing wildfire.
- Thinning and prescribed fire are proposed throughout the project area to reduce stocking levels, reduce surface and ladder fuels and change forest composition to favor more drought tolerant species. Specific recommendations are provided in this evaluation.

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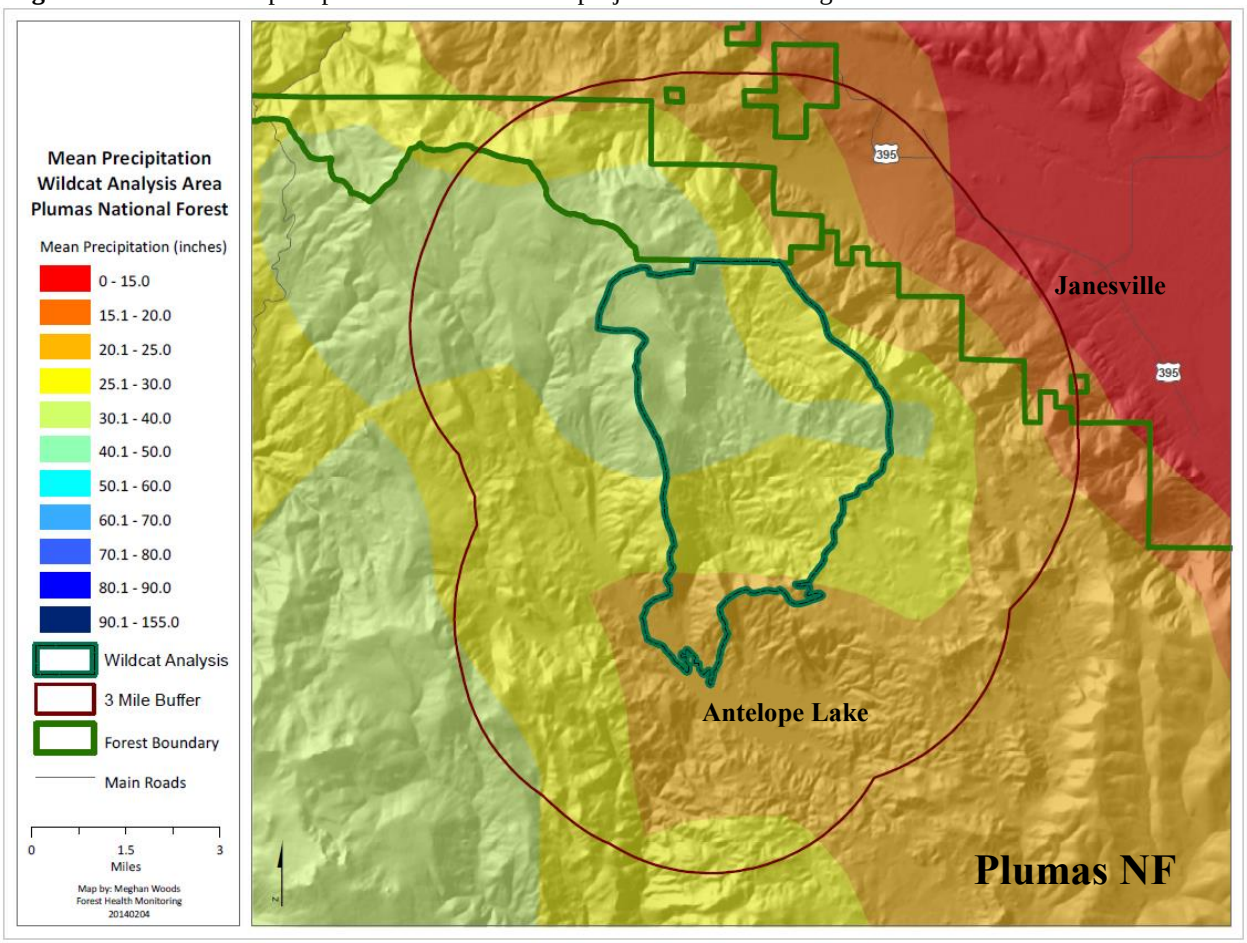
Description of the project area

The Wildcat project is located approximately 3 miles southeast of Janesville, CA at elevations ranging between 5,000 and 7,800 feet (40° 14’ 26.59”N and 120° 35’ 40.79”W). Annual precipitation ranges between 20 and 40 inches (Figure 1). Sierra mixed conifer is found at lower elevations in the south end of the project area, consisting of white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), Douglas-fir (*Psuedotsuga menziesii*), Jeffrey pine (*Pinus jeffreyi*), ponderosa pine (*Pinus ponderosa*) and incense cedar (*Calocedrus decurrens*). Jeffrey pine and white fir are found at slightly higher elevations in the north/northeast end of the project area. Red fir (*Abies magnifica*) is mixed with white fir at the highest elevations and lodgepole pine (*Pinus contorta var. murrayana*), quaking aspen (*Populus tremuloides*), alder (*Alnus sp.*) and black cottonwood (*Populus trichocarpa*) are found along riparian areas. Scouler’s willow (*Salix scouleriana*) is also scattered throughout the project area and a few California black oak (*Quercus kelloggii*) can be found near the south project boundary. Most forested areas are densely stocked, have experienced elevated levels of tree mortality associated with insects, pathogens and drought and contain high numbers of standing and down dead trees.

Figure 1. Mean annual precipitation for the Wildcat project and surrounding area.



Management objectives

The Wildcat project proposes to reduce fuels and improve forest health through thinning of mostly smaller diameter trees, grapple piling down woody debris and prescribed burning. Jeffrey

pine/white fir stands will be thinned to approximately 80 sq. ft. /acre of basal area in non-wildlife areas and approximately 120 sq. ft. /acre within wildlife areas. Mixed conifer stands and higher elevation true fir stands will retain relatively higher stocking based on local site conditions. The residual stands will be more open, increasing the amount of available soil moisture and sunlight for individual trees, and contain fewer white fir.

Forest insect and disease conditions

Bark beetle activity was observed primarily on white fir where fir engraver beetle (*Scolytus ventralis*) is causing high levels of tree mortality throughout the northern two thirds of the project area (Figures 2 & 3). One particular area of white fir mortality was associated with a relatively recent prescribed burn (year unknown) where fire-caused bole injuries appear to have weakened trees, predisposing them to fir engraver beetle attacks. Several Jeffrey pine have also been recently attacked and killed by Jeffrey pine beetle, including a few large diameter old growth trees (Figures 4 & 5).

Figures 2 & 3. White fir killed by fir engraver beetle. Trees were predisposed to beetle attack by a combination of Heterobasidion root disease, overstocking, poor growing site and drought.

Figures 4 & 5. Jeffrey pine beetle-killed Jeffrey pine. The tree on the right was also infected with western dwarf mistletoe.

Aerial detections surveys in 2013 also noted low levels of mountain pine beetle (*Dendroctonus ponderosae*) caused mortality of lodgepole pine scattered throughout the project area.

Forest tree diseases found within the project area include Heterobasidion root disease in white fir (caused by *Heterobasidion occidentalis,* formerly referred to as S-type annosus root disease), western dwarf mistletoe (*Arceuthobium campylopodum*) in Jeffrey pine and Elytroderma needle cast (caused by *Elytroderma deformans*), also in Jeffrey pine. Aerial detection surveys from 2013 also noted Marssonina leaf blight (*Marssonina populi*) on aspen within the project area.

Heterobasidion root disease in white fir appears widespread in the north half of the project area, predisposing trees to bark beetle-caused mortality. Western dwarf mistletoe is also causing severe stress to individual Jeffrey pines in several stands, also in the north end of the project area, predisposing them to bark and woodboring beetle attacks. Impacts from both of these pathogens appear to be most severe in the drier northeastern portion of the project area.

Stand conditions and mortality related to recent and future climate trends

Many of the forested areas in the Wildcat project appear to be at or above "normal" stocking levels and have exhibited an elevated level of tree mortality caused by bark beetles during and after periods of drought (Figure 6 and Table 1). This mortality combined with high stand density has resulted in heavy fuel loading in many areas and a corresponding increase in potential fire behavior.

Figure 6. Areas of elevated tree mortality mapped by Aerial Detection Surveys (ADS) between 2004 and 2013.

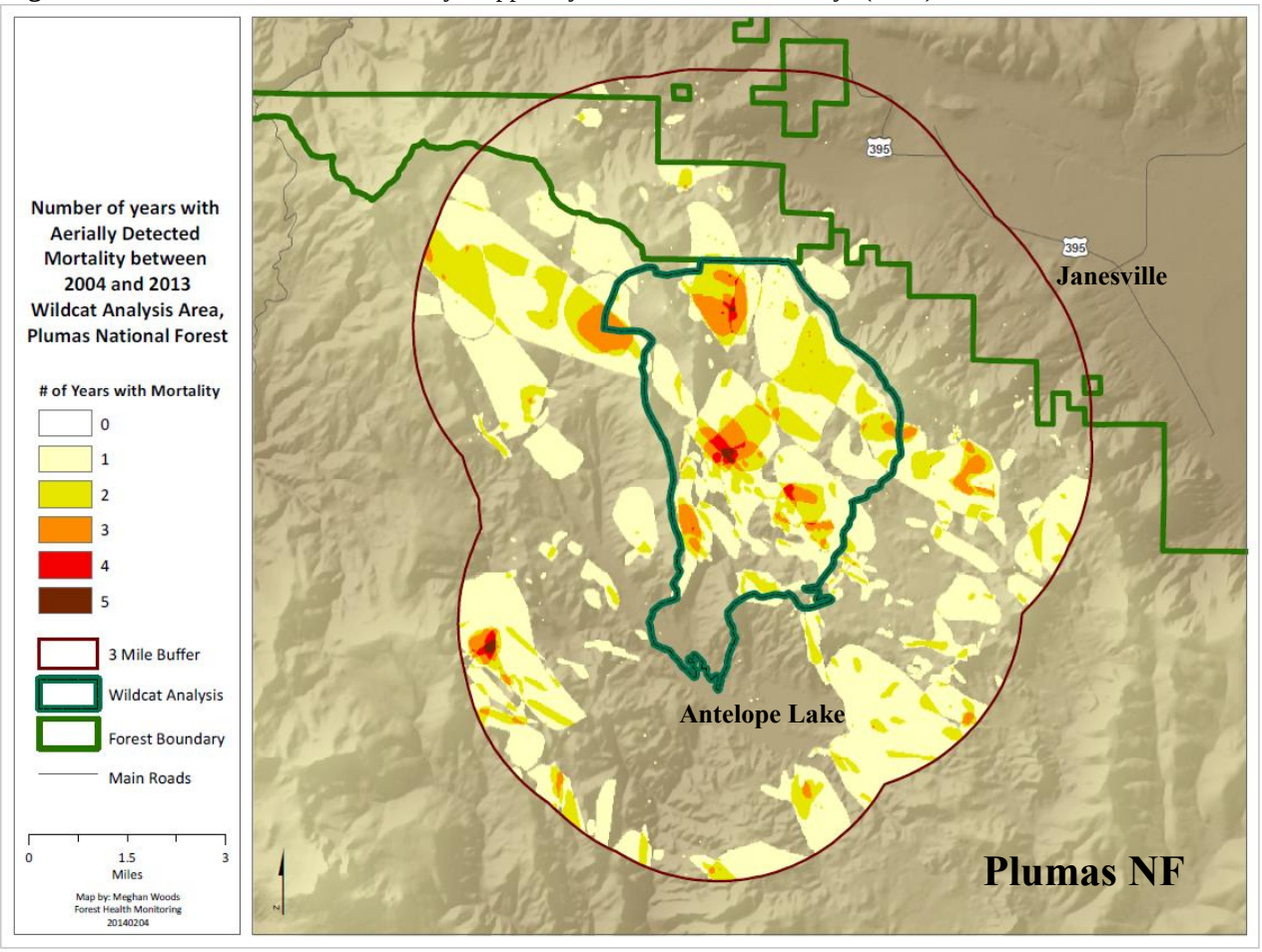


Table 1. Acres with mortality, estimated dead trees per acre and estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (average of CA Divisions 2 and 3[1]) by water year (Oct-Sept) within and adjacent to the Wildcat project area.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI[2]
2013	529	1	753	-2.15
2012	2,617	3	7,209	-0.59
2011	5,978	2	9,849	2.78
2010	6,619	3	18,501	-0.14
2009	3,947	3	10,433	-2.98
2008	176	1	191	-3.16
2007	2	3	6	-3.17
2006	59	2	123	2.40
2005	904	1	904	0.37
2004	11,617	2	17,765	-1.84

[1] California Divisions 2 and 3 encompass most of northeastern California. The Wildcat Project is on the border between these two zones.

[2] PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

Many stands are also experiencing a species composition shift from shade intolerant to more shade tolerant species. For example, Jeffrey pine was likely the dominant species in northeastern portion of the project area before the fire suppression era. White fir has increased in relative abundance and is now competing for limited soil moisture. This has resulted in the loss of some larger diameter Jeffrey pines to bark beetle attacks and a lack of Jeffrey pine regeneration due to increased shade in the understory.

Successive dry years can exacerbate unhealthy stand conditions, such as those that exist in many areas of the Wildcat project area. This typically results in higher levels of bark beetle caused tree mortality. From 2008 to 2010, tree mortality generally increased throughout northeastern California as a result of drier than normal conditions. In the Wildcat project area, tree mortality of increased dramatically in 2009 and 2010 (Table 1). A return to normal to above normal precipitation in 2010 and 2011 reduced moisture stress for all conifer species and subsequently reduced mortality levels by 2013. The current drought will most likely result in a return to increased tree mortality over the next couple of years.

White fir that succumb to fir engraver beetle attacks are typically predisposed by other factors that compromise their health and vigor. In the Wildcat project area, high stand density, prolonged drought and Heterobasidion root disease are all contributing factors in declining tree health. White fir trees in the Wildcat project area will remain susceptible to high levels of mortality until the current drought conditions subside. More top kill and additional whole tree mortality should be expected this summer due to fir engraver beetle attacks sustained in 2013.

Approximately two thirds of the Wildcat project area receives less than 30 inches of annual precipitation. This is below what is generally required for healthy white fir forests. Therefore, even with lower stocking levels, white fir growing on these sites are at a higher risk for fir engraver beetle-caused mortality during periods of drought. High stand density combined with the last prolonged drought (1987-1992) resulted in elevated levels of white fir mortality throughout the project area as evidenced by older dead and down stems from that period.

The distribution of both white fir and white fir mortality are strongly influenced by the mean annual precipitation. The lower limit of precipitation in the natural range of white fir is about 20 inches (Fowels, H.A. 1965). The isohyetal map of mean annual precipitation provided in this report (Figure 1) can be used to rate the risk of white fir mortality (Schultz 1994, FHP Report 94-2).

Low risk: 40+ inches annual precipitation (0% of Wildcat project area). These areas easily support stands of white fir and red fir. Mortality will be low, even during drought periods. Thinning will increase the rate of tree growth, but will show only slight differences in tree mortality.

Medium Risk: 30-40 inches of annual precipitation (~35% of Wildcat project area). Stands in these areas often have a high percentage of white fir that may achieve a considerable age and size. Prolonged drought may cause mortality of 5-10% of the stems. Periodic thinning which concentrates on removing white fir ingrowth will lower mortality by maintaining a more sustainable amount of biomass, as well as promoting a more stable mixed species stand.

High Risk: 25-30 inches of annual precipitation (~50% of Wildcat project area). In the absence of fire, these areas have stands which are dominated by densely stocked, small diameter white

fir. The species distribution by age class shows an increase in the relative percentage of white fir in these stands following fire suppression. Prolonged drought may cause mortality in excess of 50% of the stems. The risk of mortality can be lowered by thinning to a wide spacing prior to the onset of drought, and by promoting a mix of species that are native to the site.

Extreme risk: 20-25 inches of annual precipitation (~15% of Wildcat project area). In some cases the shade tolerant trees may live long enough to achieve an intermediate of co-dominant crown position. Prolonged drought may cause mortality of 80-85% of the stems. In stands where the total stocking of both overstory and understory is high, mortality may also occur in the pines. The risk of mortality may be lowered by managing groups of pine at wide spacing.

A white fir levels of growing stock study conducted by Cochran (1998) on the Deschutes and Fremont National Forests between 1983 and 1995 provides some additional information to consider when managing white fir in lower precipitation areas. Plots were thinned in 1982 and again in 1985 to a residual stand density index (SDI) of 112, 168, 224 or 280. These corresponded to growing stock levels of 20, 30, 40 or 50 percent of normal density. Elevations for his study plots ranged from 4,500 to 5,900 feet with average annual precipitation ranging from 16 to 31 inches. A general drought prevailed over the study areas from the late 1970's to the mid 1990's and mortality between 1991 and 1995 destroyed the study. Mortality on Blocks 2, 3 and 4 of the study was attributed to fir engraver beetles. Mortality from fir engraver beetles appeared to increase with increasing stand densities and was above acceptable levels even at the lowest stand density (20 percent of density considered normal for white fir).

Healthy stands of white fir grow very rapidly, produce a dense crown cover and are visually pleasing (Cochran 1998). Cochran's results, however, raise doubts about maintaining stands with a large component of white fir in areas with mean annual precipitation below 32 inches even if stand densities are kept very low. Cochran's study stands grew well for more than 60 years and reached commercial size before severe mortality occurred. With climate change predictions of warmer and possibly drier conditions in the future, the risk of white fir mortality in these areas will likely become even greater.

The current trend in most Wildcat stands of increasing stand density, high levels of insect and disease activity and elevated levels of mortality are likely to continue until a major disturbance event such as a stand replacing fire occurs. Large scale bark beetle outbreaks will likely also occur periodically in response to extended drought periods. In the interim, older Jeffrey pine will continue to succumb to disease, drought and bark beetle attacks and slowly be replaced by dense stands of younger shade tolerant trees. White fir will continue to succumb to fir engraver beetles after being weakened by Heterobasidion root disease. Fuel loads will continue to increase creating a higher risk of high intensity and stand replacing fire across all forest types; some of which may result in undesirable conditions such as large deforested areas.

Predicted climate change is likely to impact trees growing in the Wildcat over the next 100 years. Although no Plumas National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and*

Lassen National Forests. The risk of bark beetle caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

Considerations for thinning treatments

The proposed thinning treatments for the Wildcat project should effectively reduce inter-tree competition for limited water and nutrients and reduce the risk of insect and disease-caused mortality for most areas.

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines, and drier areas dominated by Jeffrey pine should benefit by having the stocking around them reduced to lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees. Incorporating the concepts of GTR 220 will address many of these issues and be consistent with Region 5 ecosystem restoration goals. Many of these methods are also consistent with past Forest Health Protection recommendations for thinning in mixed conifer stands and their use is supported for the Wildcat project.

When implementing thinning projects, retaining more drought tolerant pine species as well as Douglas-fir and incense cedar over white fir will increase species diversity and make stands more resilient to disturbance. This is especially true in areas where Jeffrey pine is heavily encroached by white fir. Significantly reducing the amount of white fir in these areas will provide openings for Jeffrey pine regeneration and can substantially reduce present and future fuels loads created by dead and dying white fir. In addition, when selecting trees for removal, preference should be given to trees heavily infected with dwarf mistletoe, root disease and trees infested with bark beetles. Small group harvest could be utilized to remove white fir that are within known Heterobasidion root disease centers. This would create openings that could be planted with non-host species.

Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. *C. ribicola*, a non-native pathogen, has continued to weaken and kill 5-needle pines over most of their range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created through thinning operations with rust resistant stock would help insure this species persists in the area.

Effectively managing dwarf mistletoe infection levels within Jeffrey pine stands will require the removal or killing of heavily infected trees. Young Jeffrey pine establishing under an infected overstory will most likely become infected and not reach maturity. It may be desirable to remove or kill infected overstory trees from some areas to allow for healthy stand regeneration. Removal of all heavily infected trees, especially heavily infected trees in the overstory, combined with general stand thinning will reduce the spread of mistletoe to insignificant levels while increasing the health and vigor of trees with light infections. The retention of non-host species should be emphasized during all dwarf mistletoe treatments to increase species diversity and provide

barriers to dwarf mistletoe seed spread. However, maintaining non-host white fir may not be possible over the long-term in drier sites.

It is recommended that a registered borate compound be applied to all freshly cut conifer stumps >14" in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity. An exception to this recommendation would be in Jeffrey pine/white fir stands where the existing high level of Heterobasidion root disease in white fir makes the treatment of white fir stumps ineffective.

Considerations for Rx fire

If prescribed fire is used as a follow-up treatment to stand thinning or as a standalone treatment, unacceptable levels of large diameter pine mortality may occur depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature Jeffrey, ponderosa and especially sugar pines are susceptible to mortality during prescribed burns because of the deep duff and litter that has accumulated at their base in the absence of fire. These duff mounds typically burn at a slow rate, while maintaining lethal temperatures, causing severe cambium injury. To protect individual large diameter pine from lethal cambium injury, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

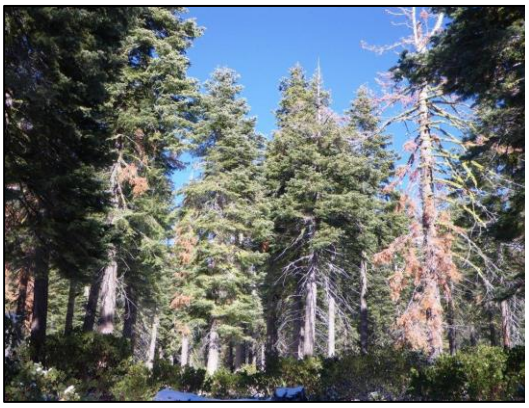


Figure 7. Dead and dying fire-injured white fir burned in a prescribed fire within the Wildcat project

White fir dominated stands tend to have very high levels of course woody debris on the forest floor as a result of downed logs from self-thinning, the continual shedding of branches and the remaining stems from old stands of brush that have been overtopped and killed by dense fir canopies. These types of stands produce tremendous amounts of heat on the ground surface and often cause severe injuries to the boles and crowns of standing trees, especially to smaller diameter trees. If high post-burn mortality levels in white fir stands, resulting in openings and possibly additional heavy fuel loading, is not an acceptable condition, than fuel treatments such as hand or tractor piling should be considered prior to or in place of prescribed fire. An example of post-prescribed fire white fir mortality exists at the north end of the project area along FS Road 29N99 (Figure 7).

Potential for funding thought the Western Bark Beetle Program

Forest Health Protection may be able to assist with funding, including NEPA activities, for thinning and removing green material from overstocked areas within the Wildcat project area. Thinning treatments that reduce stand density sufficient to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

/s/ Danny Cluck

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Jeffrey pine beetle

The Jeffrey pine beetle is the principle bark beetle found attacking Jeffrey pine, which is its only host. It is a native insect occurring from southwestern Oregon southward through California and western Nevada to northern Mexico. The beetle normally breeds in slow-growing, stressed trees. The beetles prefer trees which are large, mature, and occur singly rather than in groups. Yet when an epidemic occurs, the beetle may attack and kill groups of trees greater than 8 inches in diameter, regardless of age or vigor. Often the beetle infests lightning-struck or wind-thrown trees, but does not breed in slash.

Evidence of Attack

Presence of the beetle is usually detected when the foliage changes color. The color change of the foliage is related to the destruction of the cambium layer by the beetle. Generally, the top of the crown begins to fade in a slow sequence, with the needles turning from greenish yellow, to sorrel, and finally to reddish brown. By the time the tree is reddish brown, the beetles have usually abandoned the tree. Another sign of beetle attack is large, reddish pitch tubes projecting from the bark of the infested tree. If examined carefully, pitch tubes can be detected on infested green trees prior to crown fade. Jeffrey pine beetles have a distinctive "J" shape egg gallery pattern on the inner bark. Larval mines extend across the grain and end in open, oval-shaped pupal cells.

Life Stages and Development

The Jeffrey pine beetle is one of the larger pine bark beetles in California. The beetle has a 4 life stages, egg, larva, pupa, and adult. The adults are stout, cylindrical, black, and approximately five-sixteenths of an inch long when mature. The egg is oval and pearly-white. The larva is white, legless, and has a yellow head. The pupa is also white but is slightly smaller than the mature larva. The life cycle is normally completed in one year in the northern part of the range, but in the southern part, two generations per year may occur. The principle period of attack is in June and July, but attacks also are frequent in late September and early October. Similar to other *Dendroctonus* species, Jeffrey pine beetles use pheromones that attract other beetles to a tree, causing a mass attack that tends to overcome the tree's natural resistance. Blue stain fungi are associated with Jeffrey pine beetle attacks and aid in overcoming the tree’s defenses.

Conditions Affecting Outbreaks

Normally the Jeffrey pine beetle is kept in check by its natural enemies, climatic factors and the resistance of its host. Similar to other *Dendroctonus* species, the availability of suitable host material is a key factor influencing outbreaks. Healthy trees ordinarily produce abundant amounts of resin, which pitches out attacking beetles. When deprived of moisture, or stressed by other factors such as disease or fire injury, trees cannot produce sufficient resin flow and become susceptible to successful beetle attacks.

Fir engraver beetle

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4” in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year; however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Mountain pine beetle

The mountain pine beetle, *Dendroctonus ponderosae*, attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

Evidence of Attack

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. In addition to pitch tubes, successfully infested trees will have dry boring

dust in the bark crevices and around the base of the tree. Attacking beetles carry the spores of blue-staining fungi which develop and spread throughout the sapwood interrupting the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

Life Stages and Development

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is typical, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other females until a mass attack overcomes the tree. The adults bore long, vertical, egg galleries and lay eggs in niches along the sides of the gallery. The larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

Conditions Affecting Outbreaks

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and pine mortality increases.

Heterobasidion root disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more

frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentalis* (also called the 'S' type) and *H. irregularis* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregularis* ('P' type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentalis* ('S' type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentalis* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

Elytroderma needle cast

Elytroderma disease (*Elytroderma deformans)* is mainly a disease of ponderosa and Jeffrey pines but other pines are infected. Diagnostic symptoms include reddening of needles in the spring, compact globose

witches' brooms, with ends tending to turn upward, brown necrotic flecks in the inner bark of infected twigs and elongate narrow dull black fruiting bodies which can often, but not always, be found on needles.

Spores are released in late summer and early fall from fruiting bodies (hysterothecia) borne on infected needles. The spores are carried by wind to current-year needles. Under proper microclimatic conditions, the spores germinate and infect these needles, which do not die until the following year. Unlike other needle pathogens, this fungus spreads throughout the needles and into the twigs. It can then spread further into growing tips and buds, infecting and deforming new growth. The microclimatic conditions favorable to infection are not well understood; however, certain areas, such as around lakes and along stream bottoms, appear to be more favorable to repeated infection.

Elytroderma disease is the most important needle cast disease of ponderosa and Jeffrey pines in western North America. It is most severe on seedlings, saplings, and poles with poor crowns. This fungus causes the premature death of 1-year old needles and a brooming and deformation of infected twigs and branches. The effect of the disease depends on the proportion of the host's crown that is diseased. There is little effect upon the host until more than two-fifths of the twigs are blighted. In forest stands, control of elytroderma disease is rarely necessary or economical.